

# **Radiation-hardened Non-volatile Memory for Europa Orbiter:**

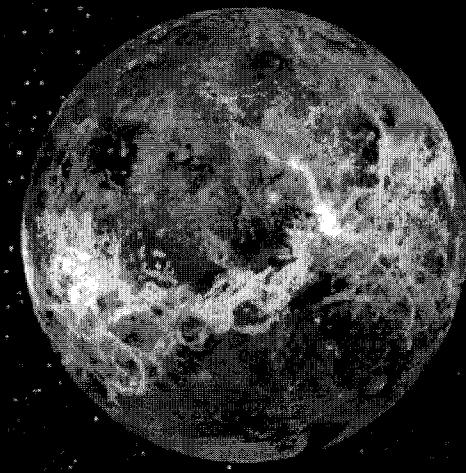
**Why do we need it?  
What do we need?**

**Non-volatile Memory Symposium 2000**  
2000 November 15, Arlington, Virginia

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MERCURY  
4,878 KM  
(3,024 MI)



VENUS  
12,100 KM  
(7,502 MI)



EARTH  
12,756 KM  
(7,909 MI)



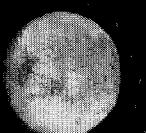
MARS  
6,786 KM  
(4,214 MI)



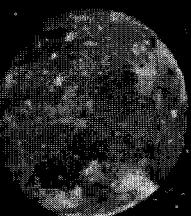
MOON (EARTH)  
3,476 KM  
(2,155 MI)



IO (JUPITER)  
3,630 KM  
(2,251 MI)



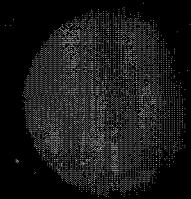
EUROPA (JUPITER)  
3,138 KM  
(1,946 MI)



GANYMED (JUPITER)  
5,282 KM  
(3,262 MI)

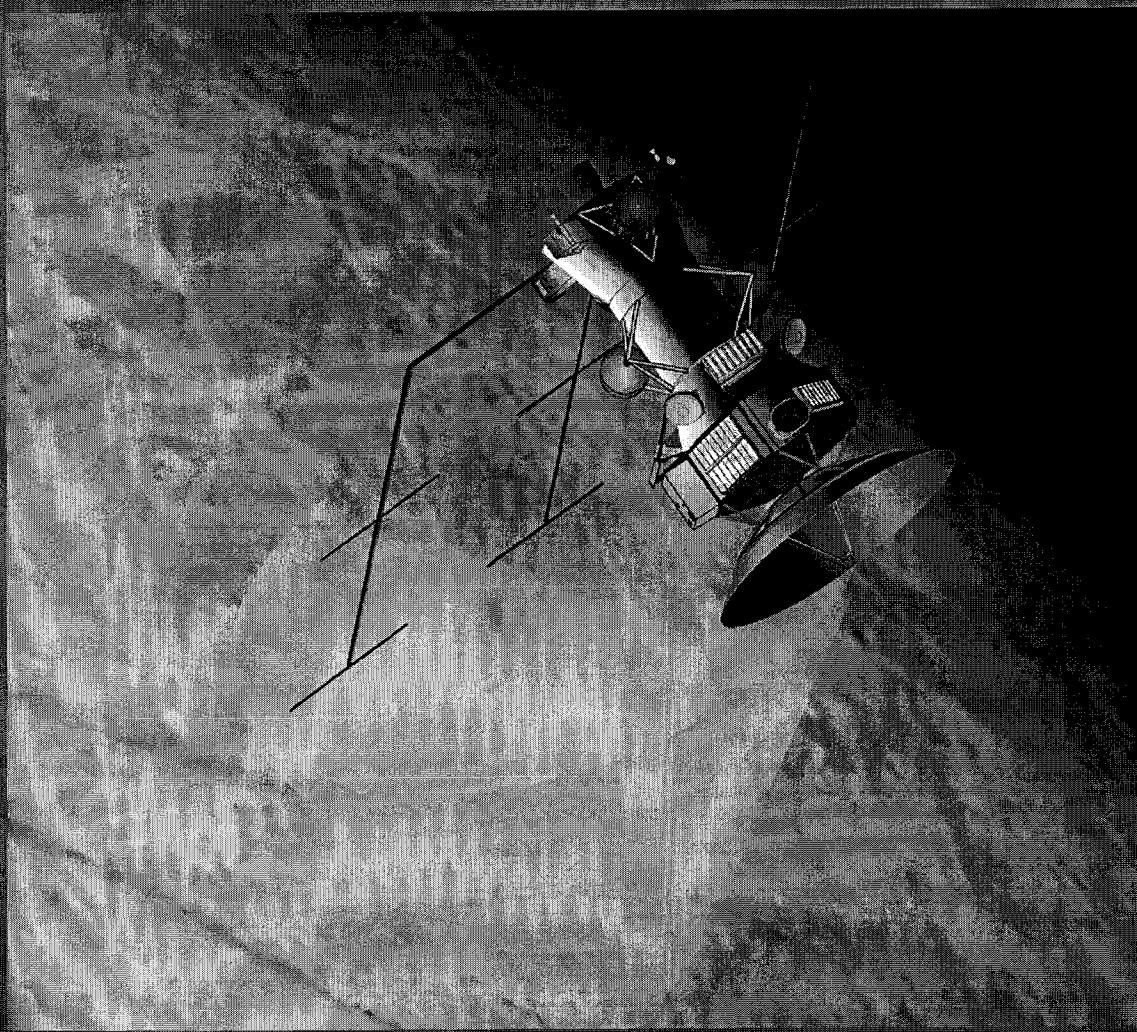


CALLISTO (JUPITER)  
4,800 KM  
(2,976 MI)

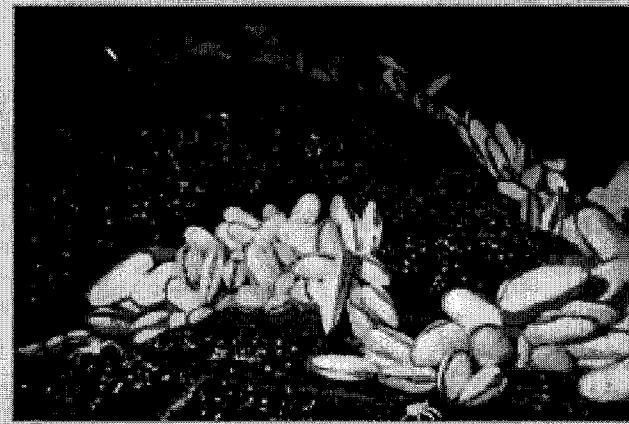
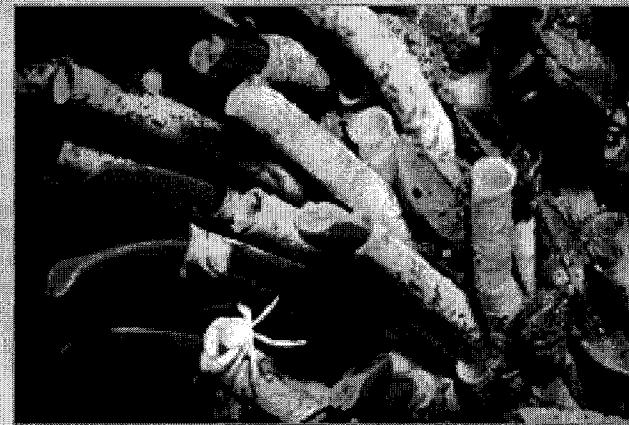
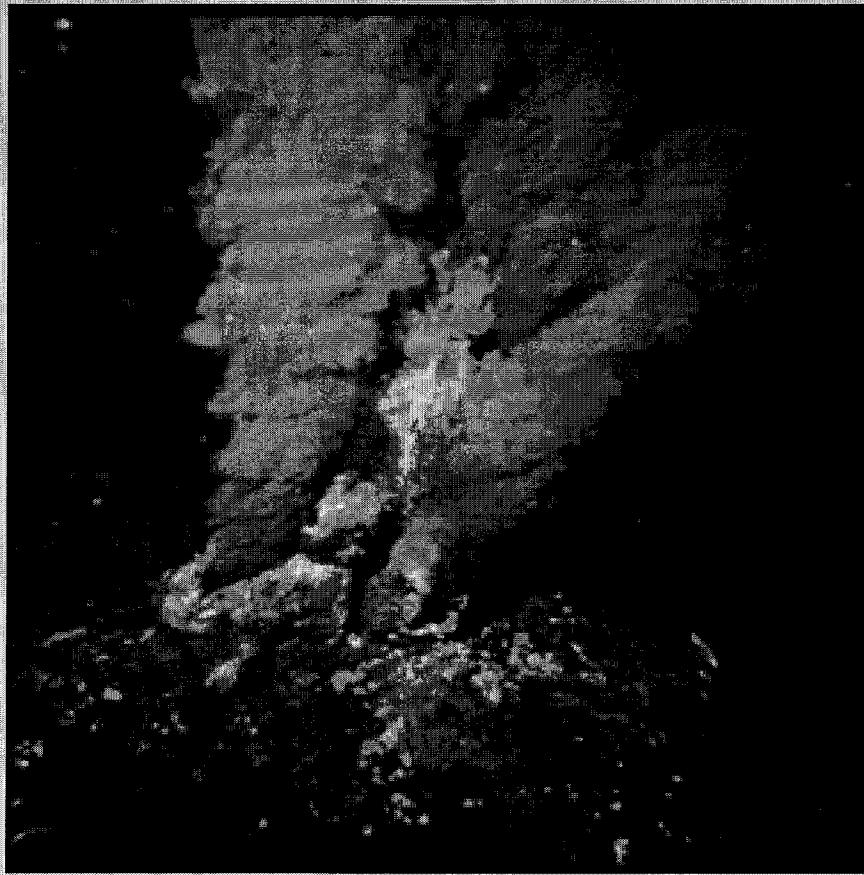


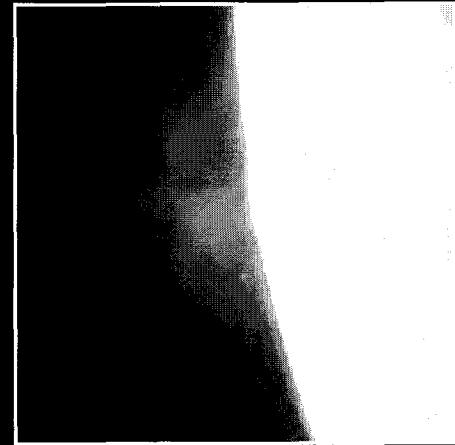
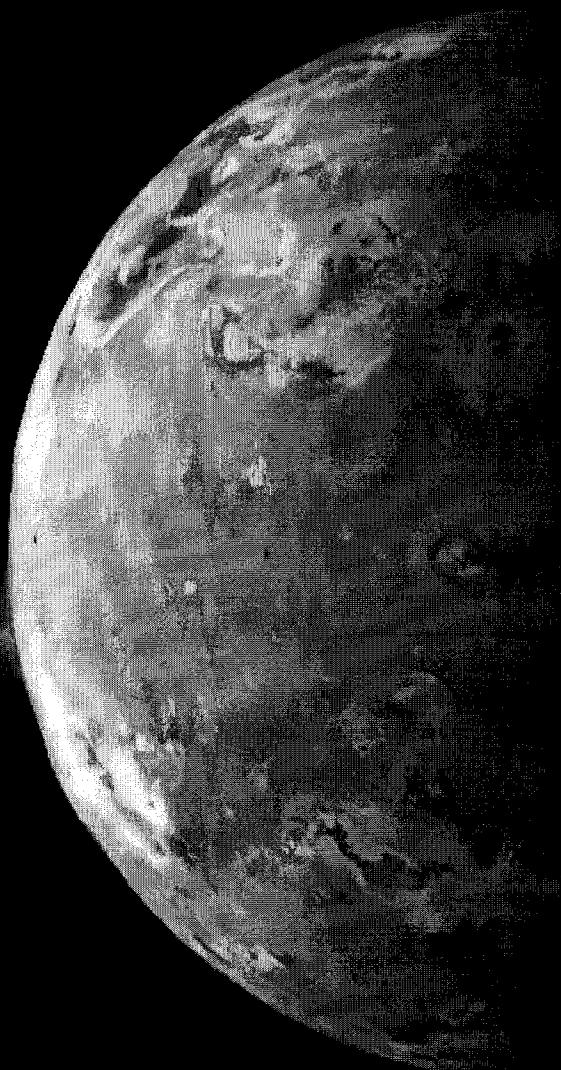
TITAN (SATURN)  
5,150 KM  
(3,193 MI)

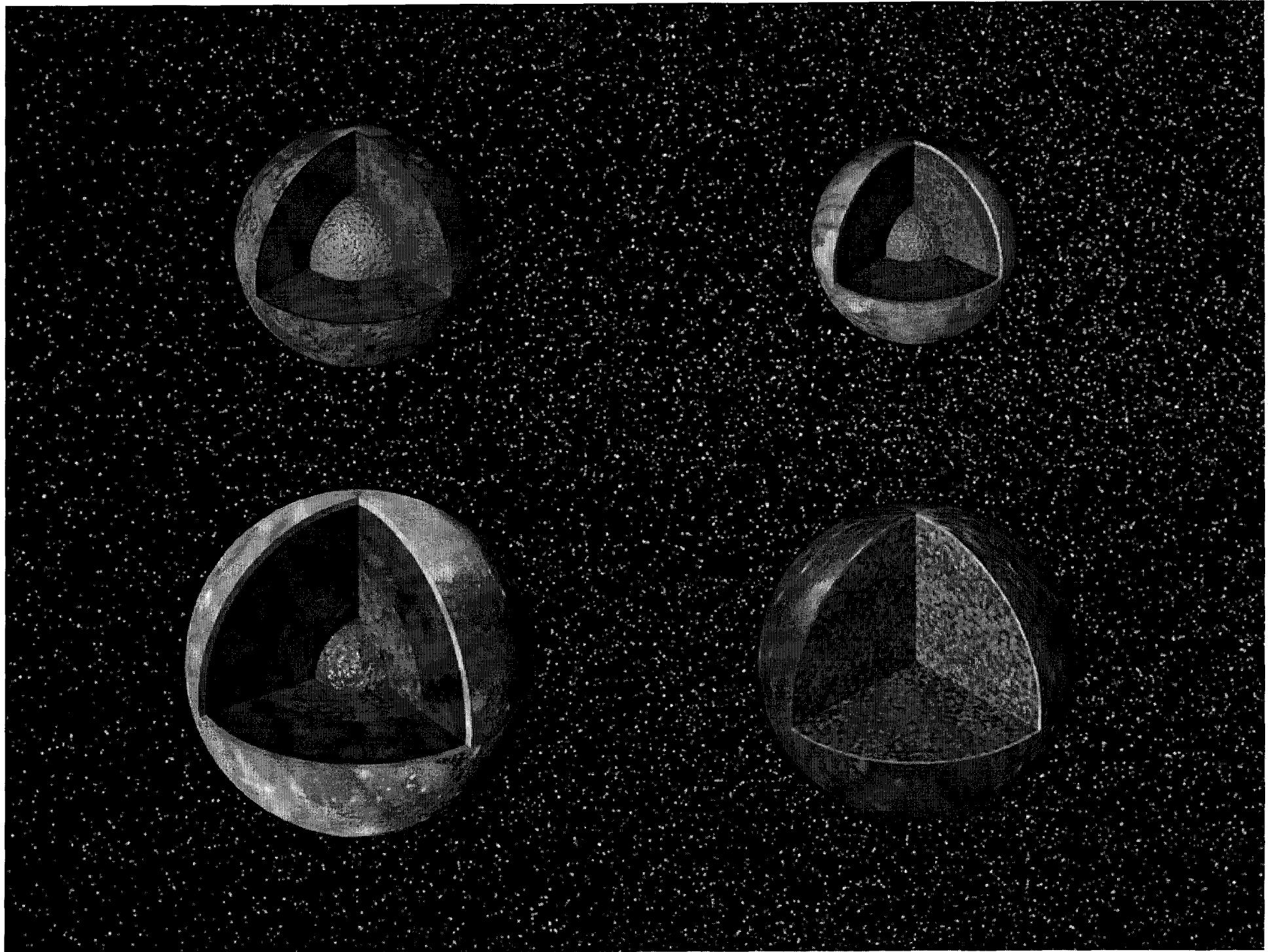
# EuropaOrbiter

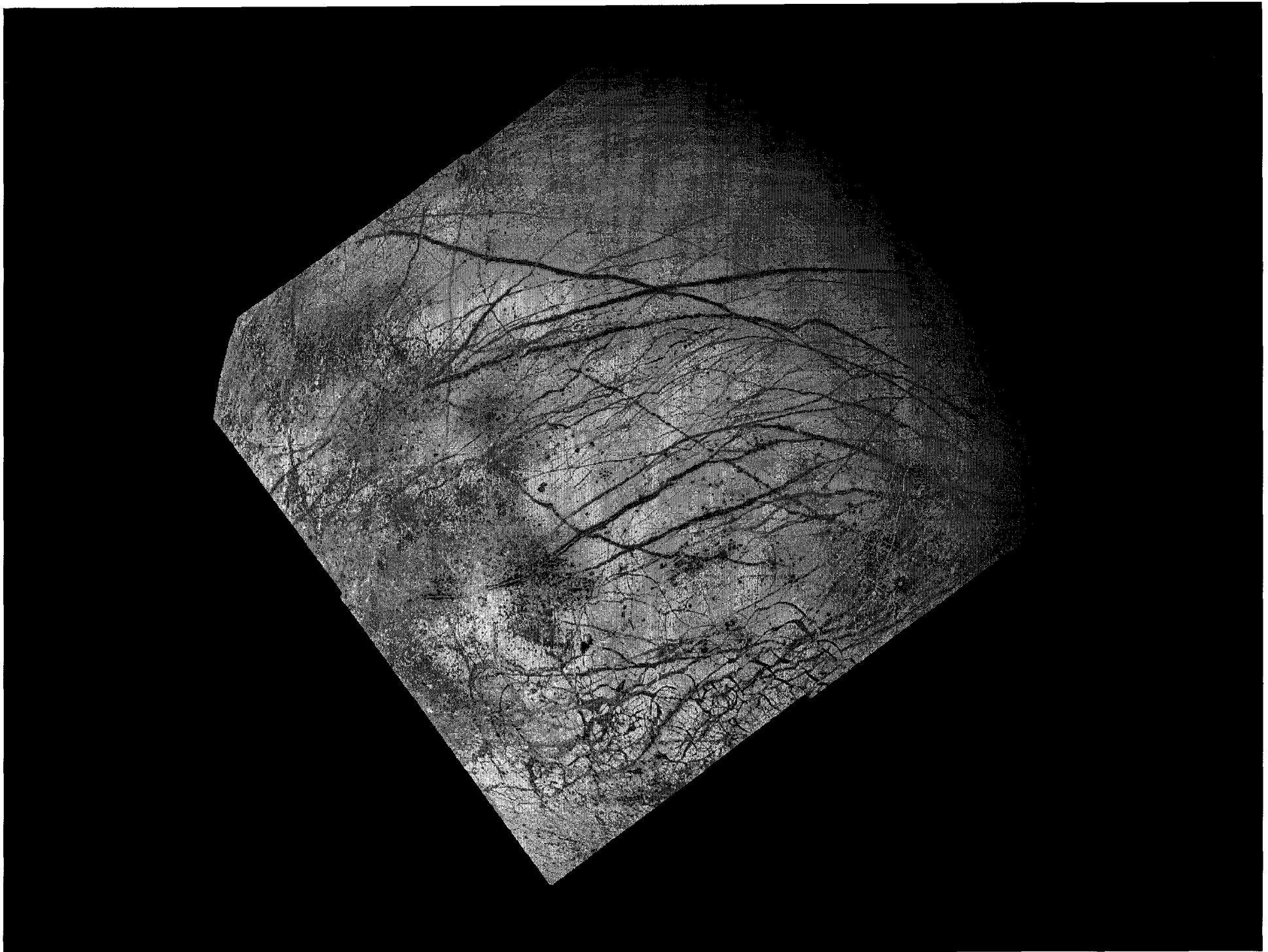


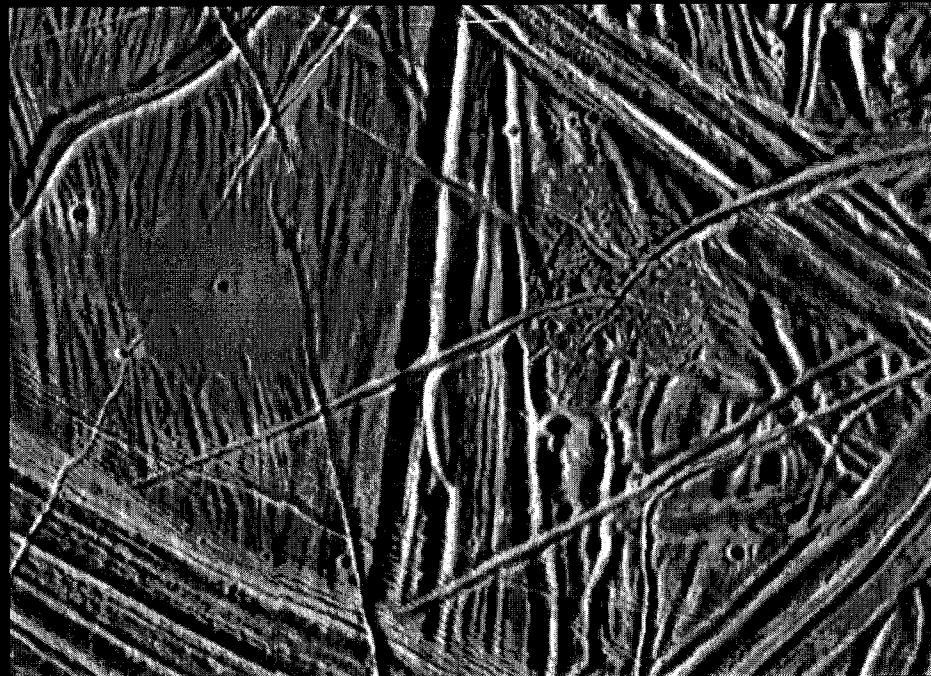
# What did we discover?





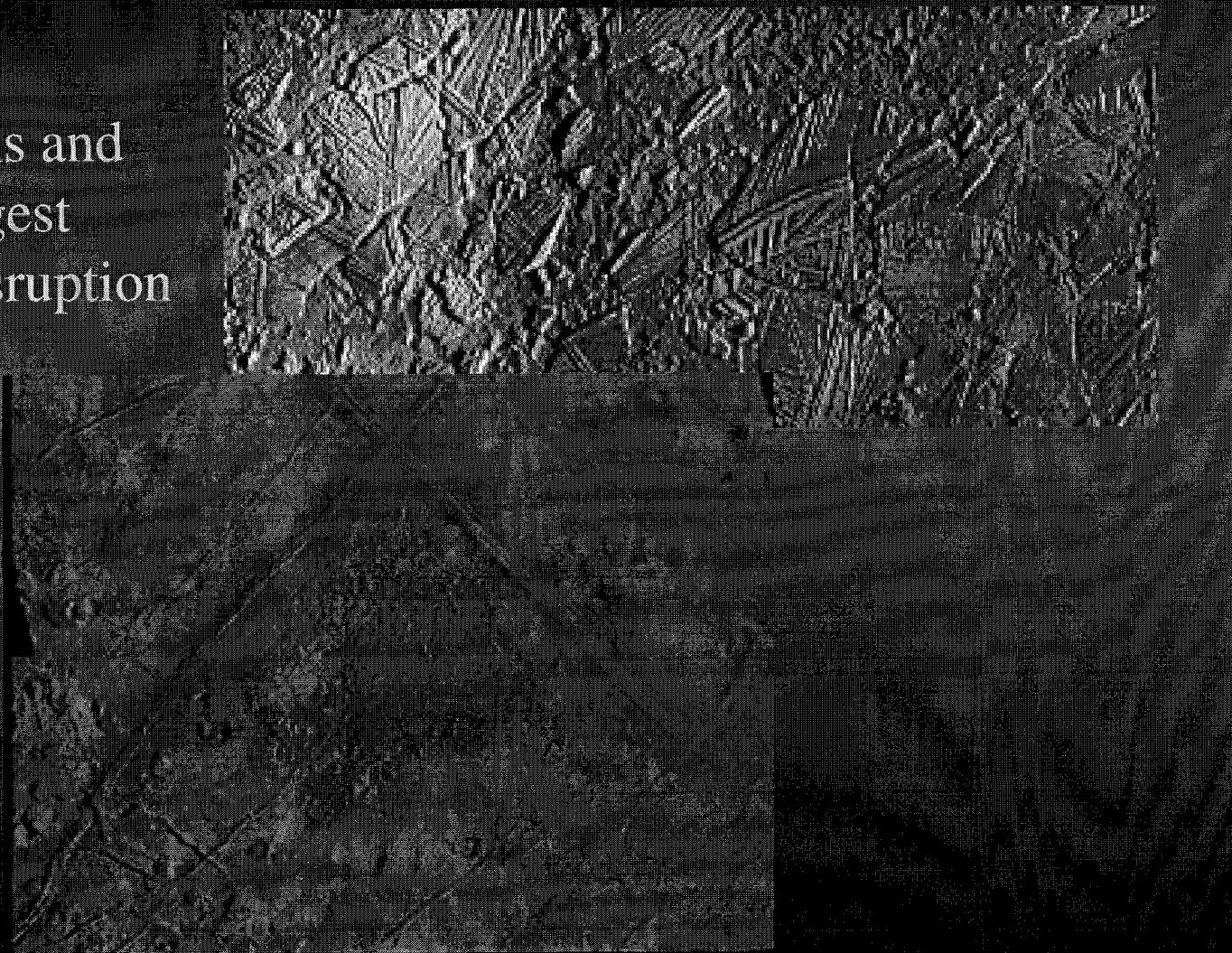


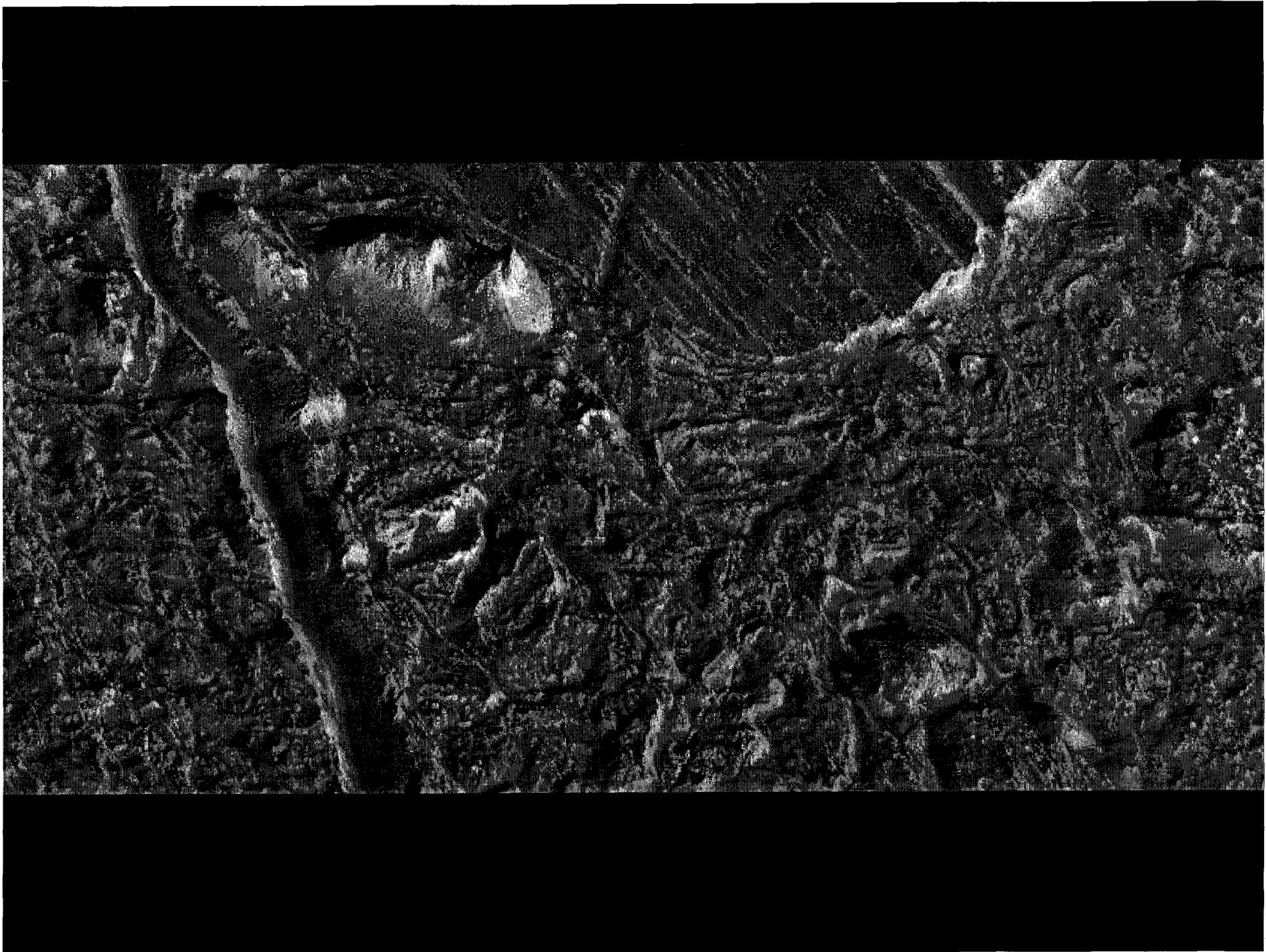


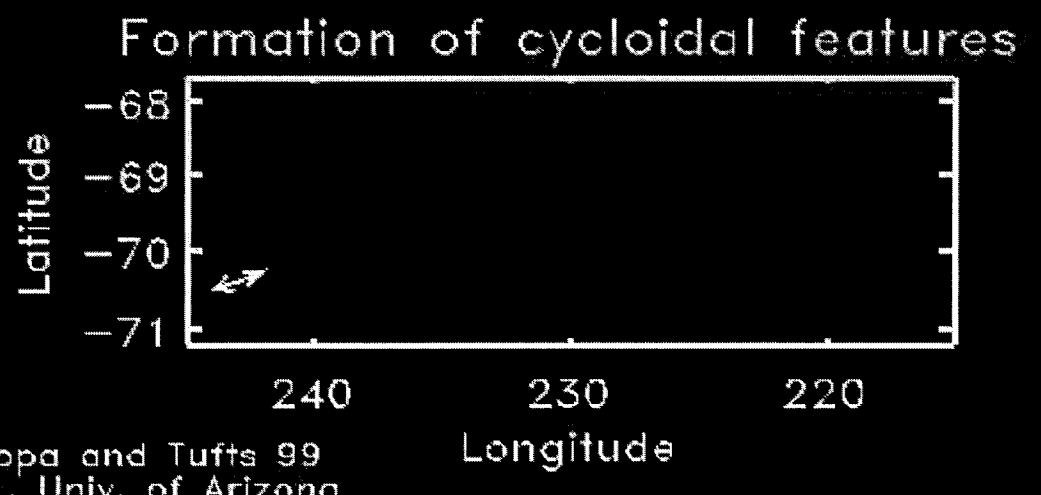
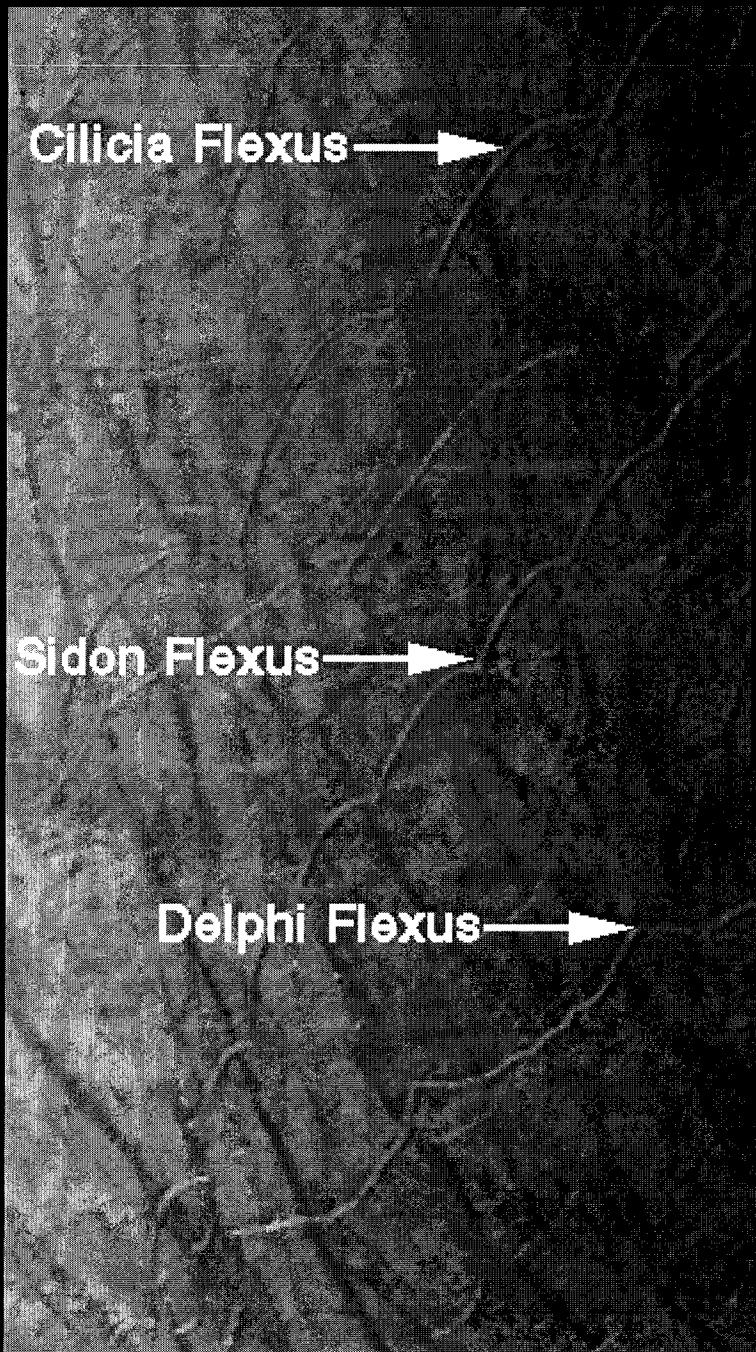


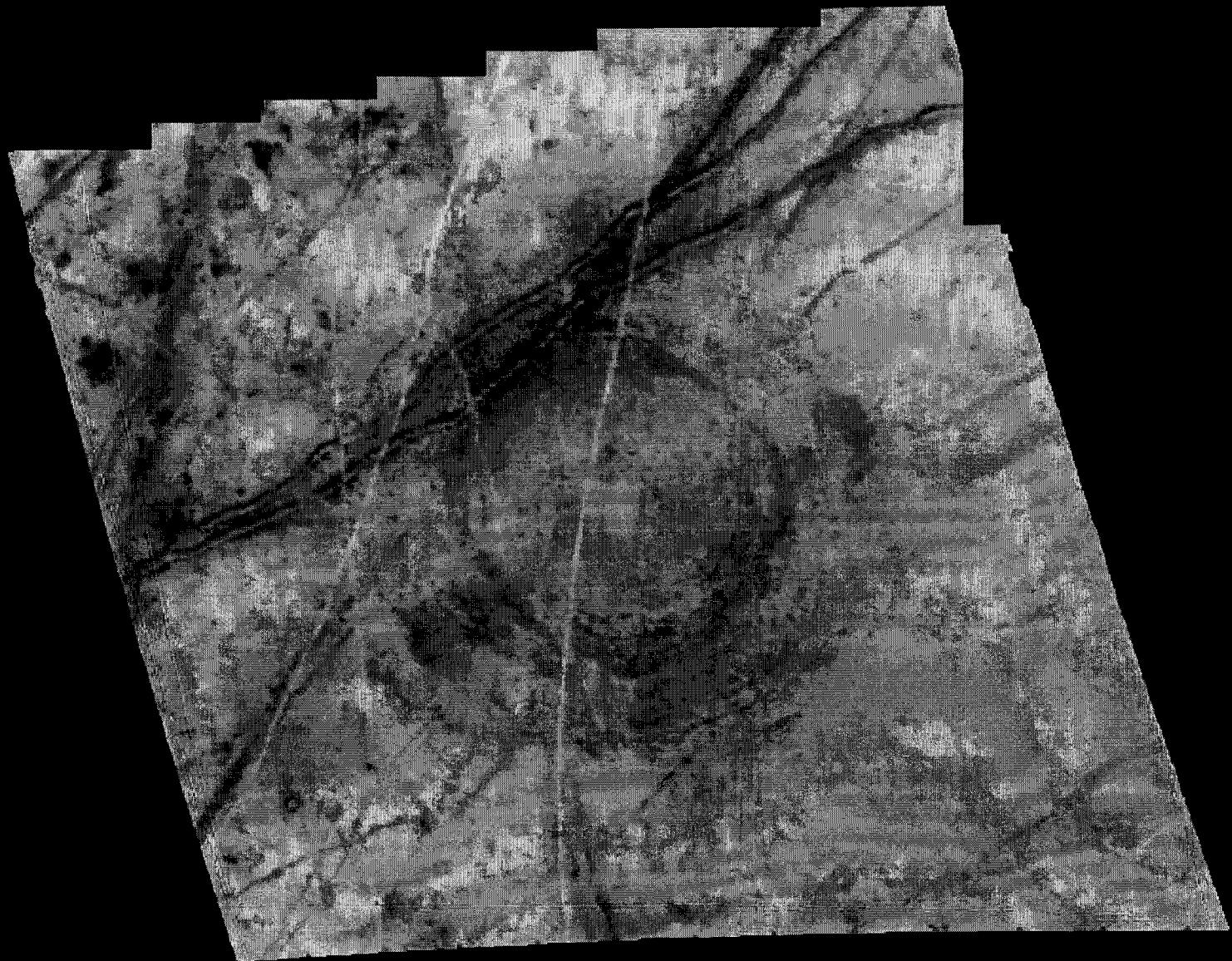
# *Did* Europa have an Ocean?

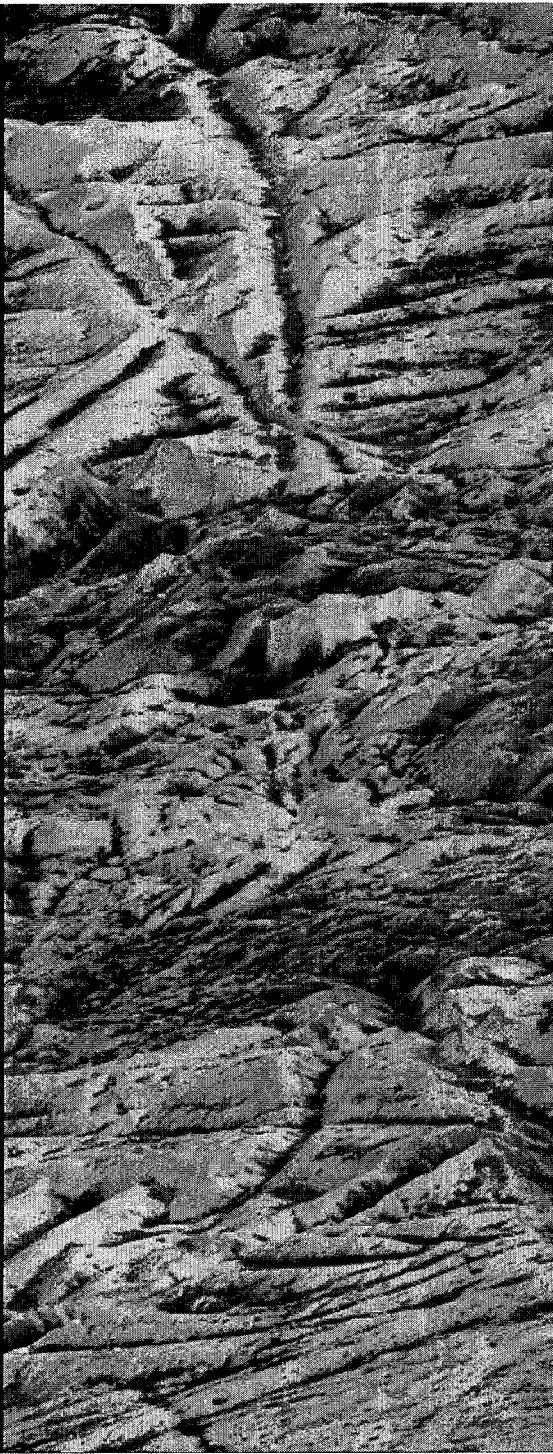
- Chaos regions and “ice rafts” suggest melting and disruption of the surface







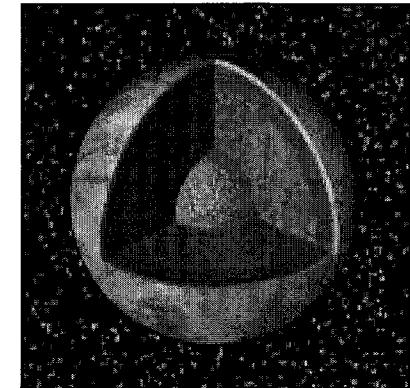
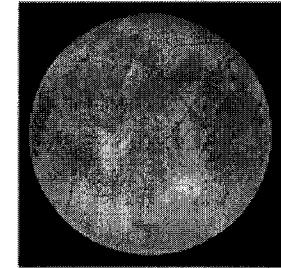
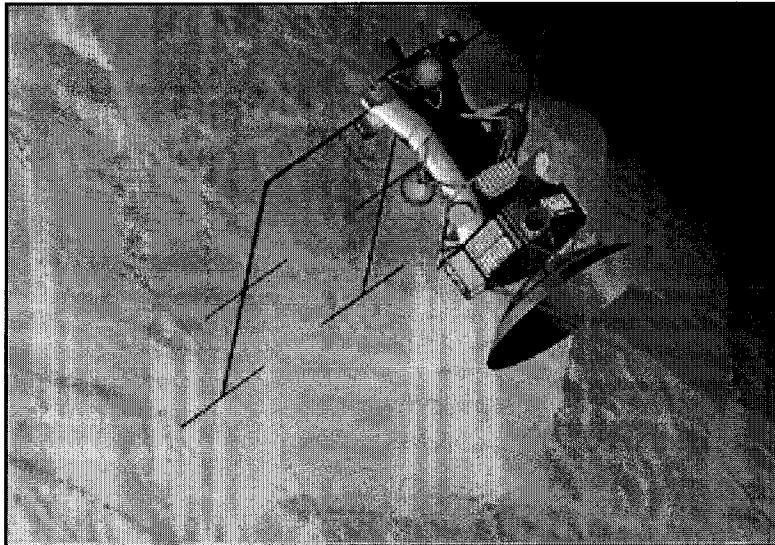




## ***Europa Orbiter Mission***

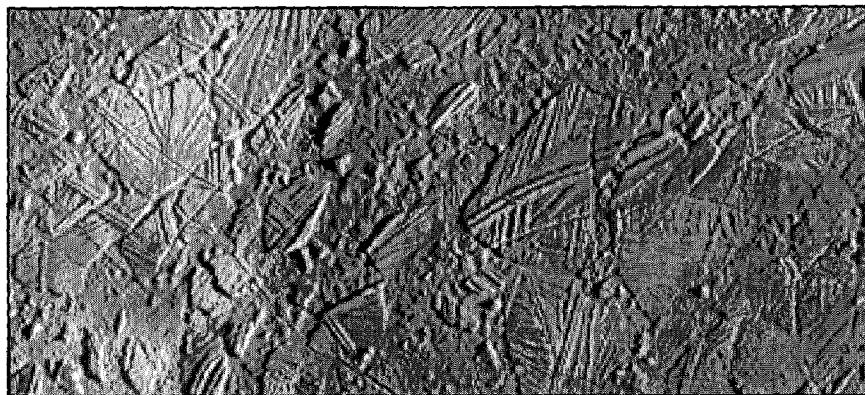
### ***Key Questions:***

- Is there an ocean of liquid water beneath Europa's ice?
- Are there places where the ice is thin or where water reaches the surface?
- Could the Europa environment support pre-biotic chemical processes?





## *Europa Orbiter Science Philosophy*



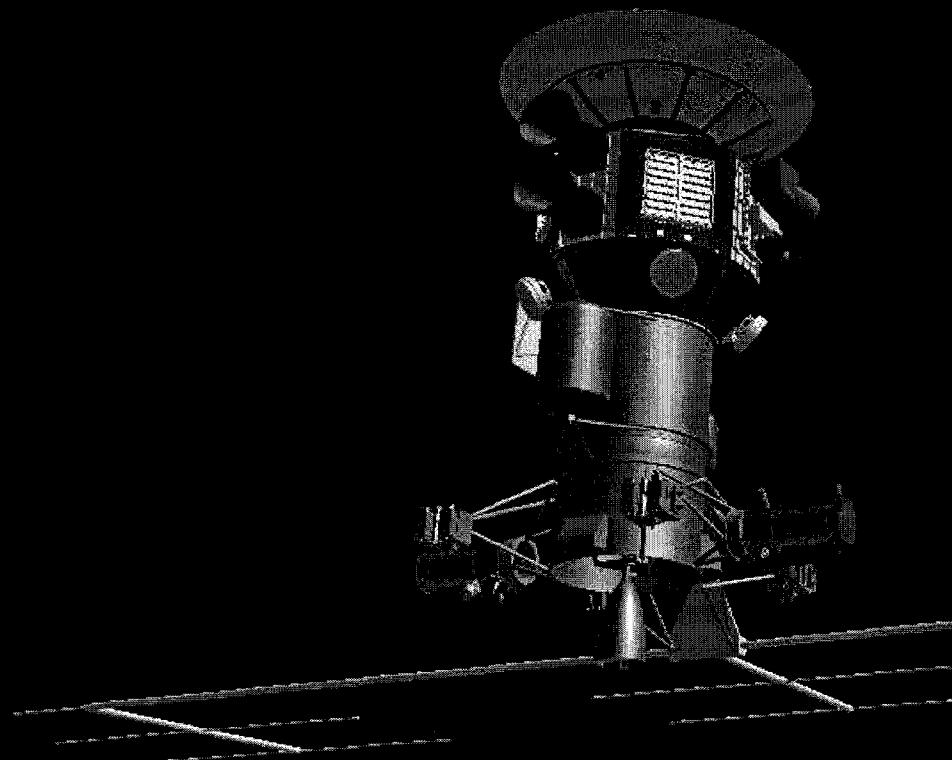
- **TIDES:** Key to the possible existence of an ocean, key to determining if it is there now
  - If “frozen ocean”: diurnal tide (3.5 d period) is a few meters
  - If liquid global ocean: diurnal tide is approximately 30 meters
  - **Consequence:** Measurements should tell us if “frozen” or “liquid” ocean
- **FUTURE EXPLORATION:** If there is an ocean, it will drive future exploration strategies, leading to landers, etc.
  - **Consequence:** Europa Orbiter must be capable of characterizing the surface, the structure of the ice crust, and the subsurface



# Outer Planets/Solar Probe Project

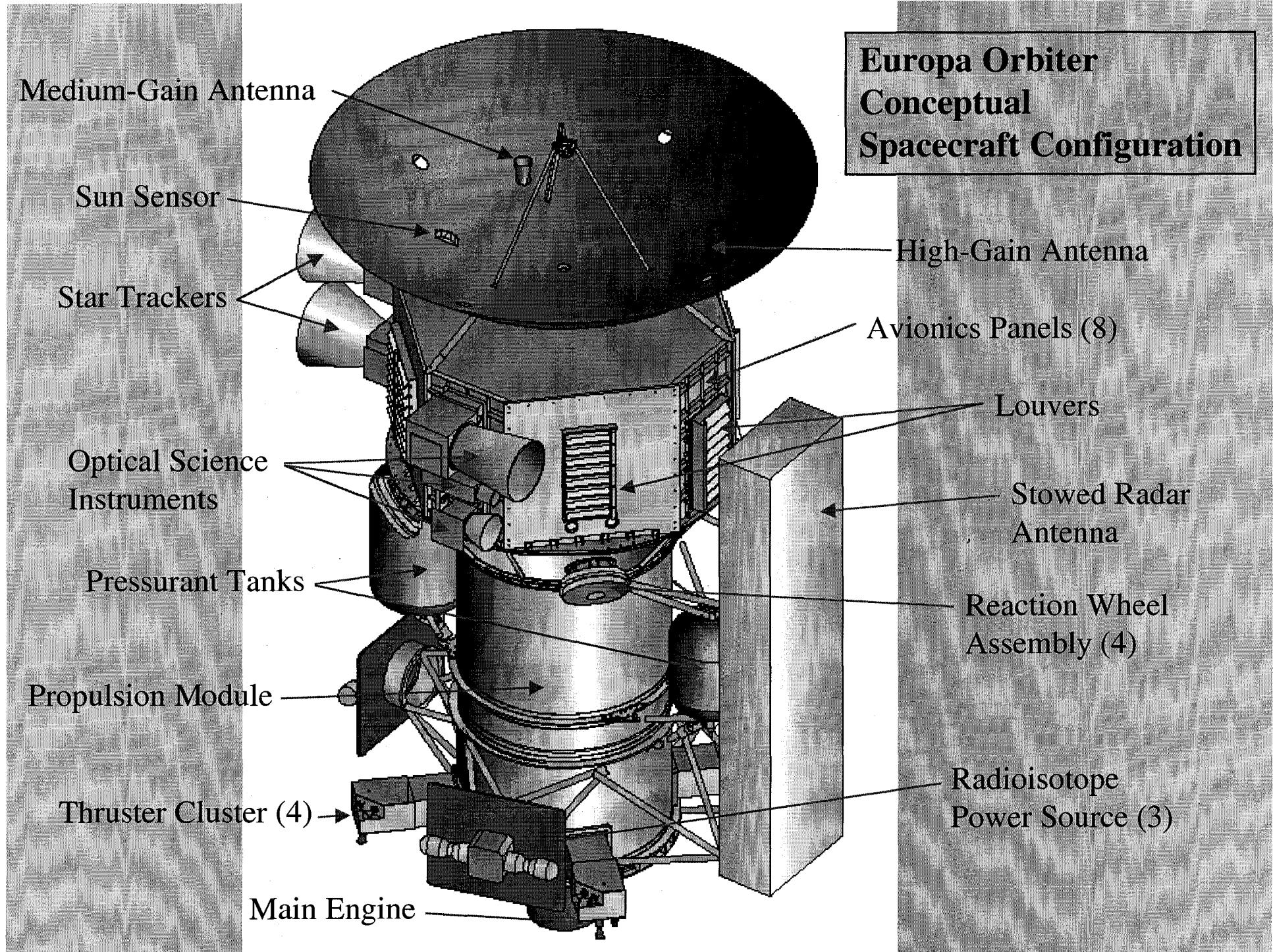
JPL

## Europa Orbiter 1A SCIENCE OBJECTIVES

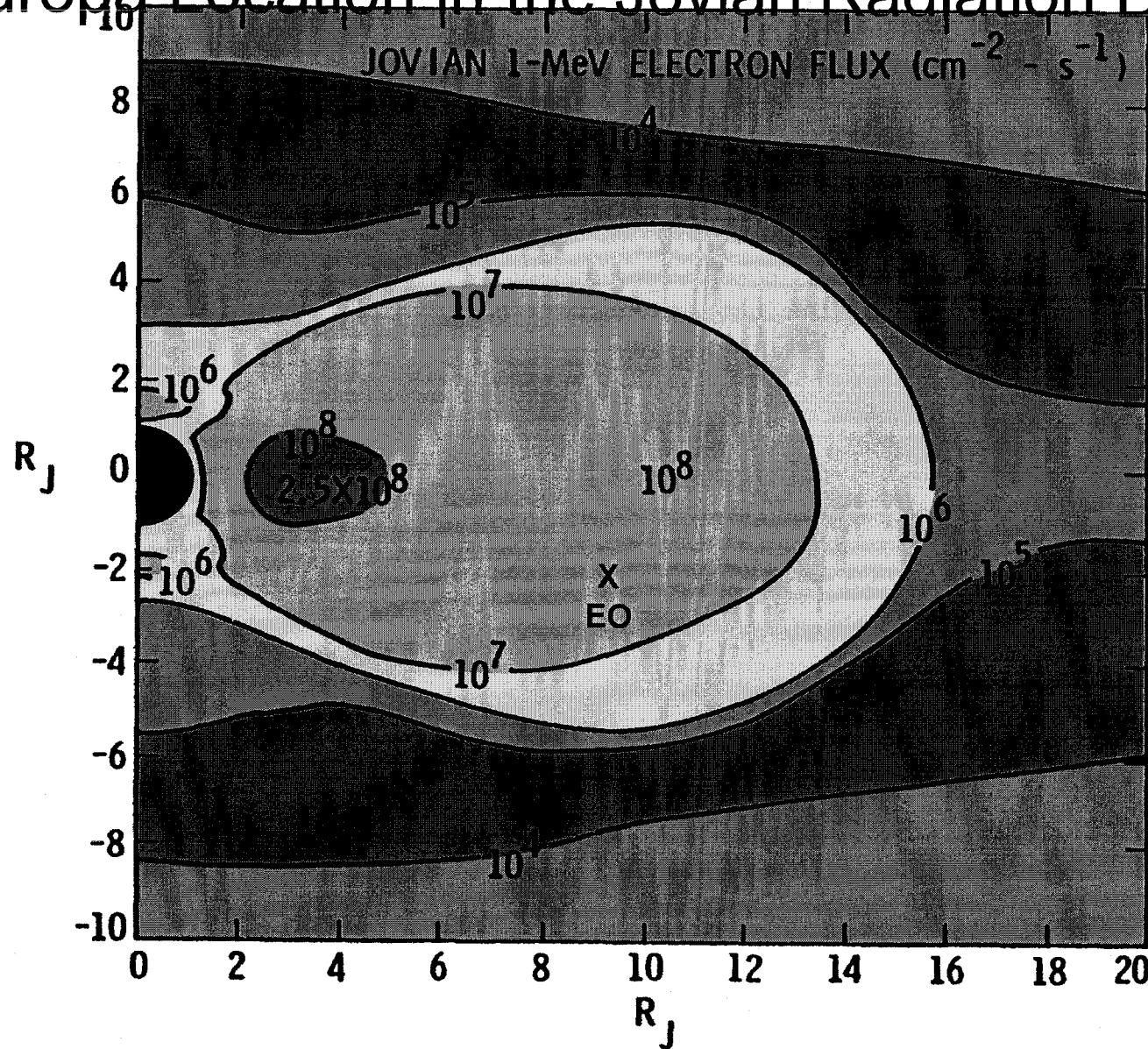


- (1) Determine the presence or absence of a subsurface ocean
- (2) Characterize the 3-D distribution of any subsurface liquid water and its over-lying ice layers
- (3) Understand the formation of surface features including sites of recent or current activity, and identify candidate sites for future lander missions

## Europa Orbiter Conceptual Spacecraft Configuration



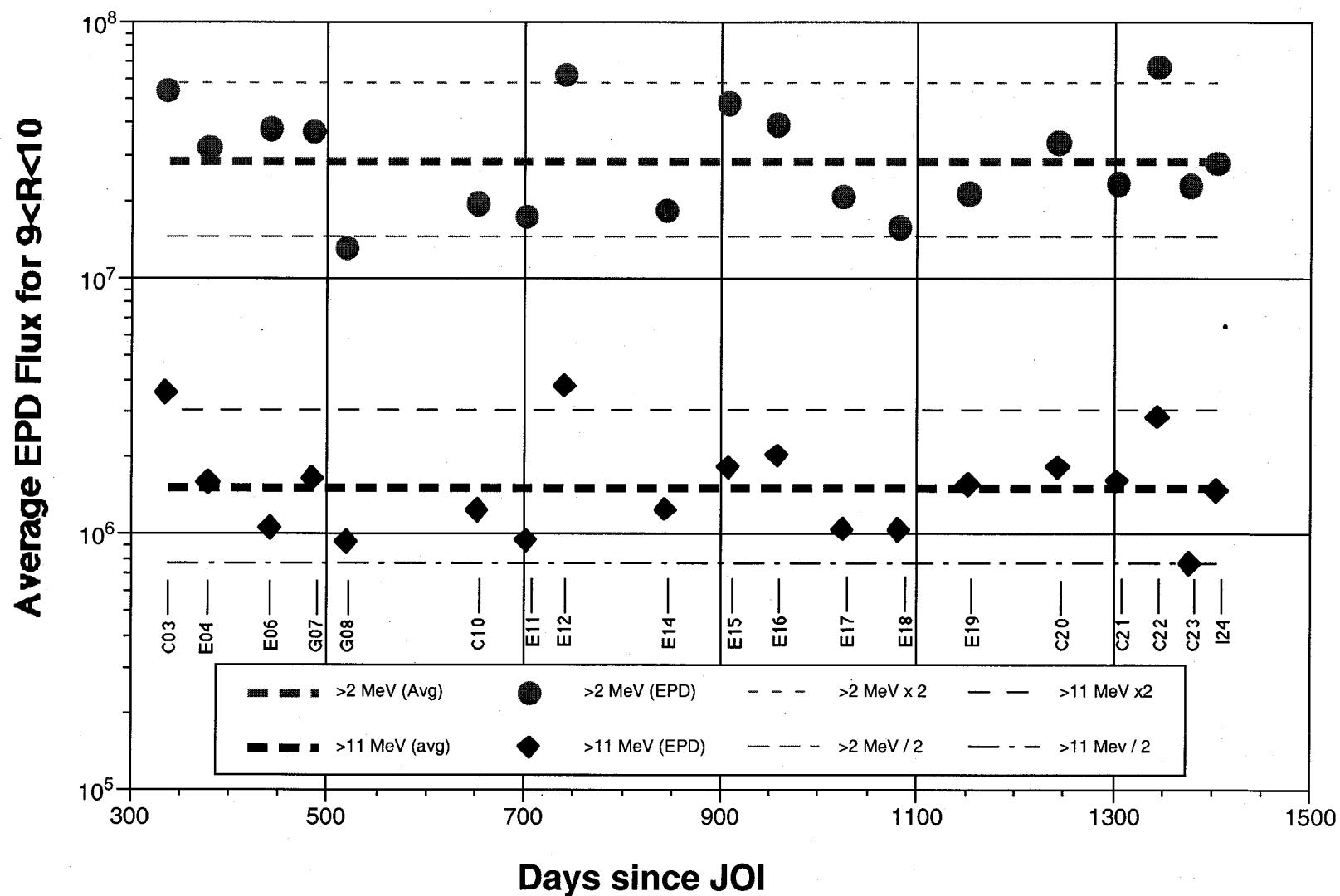
# Europa Location in the Jovian Radiation Belts



2000/11/7

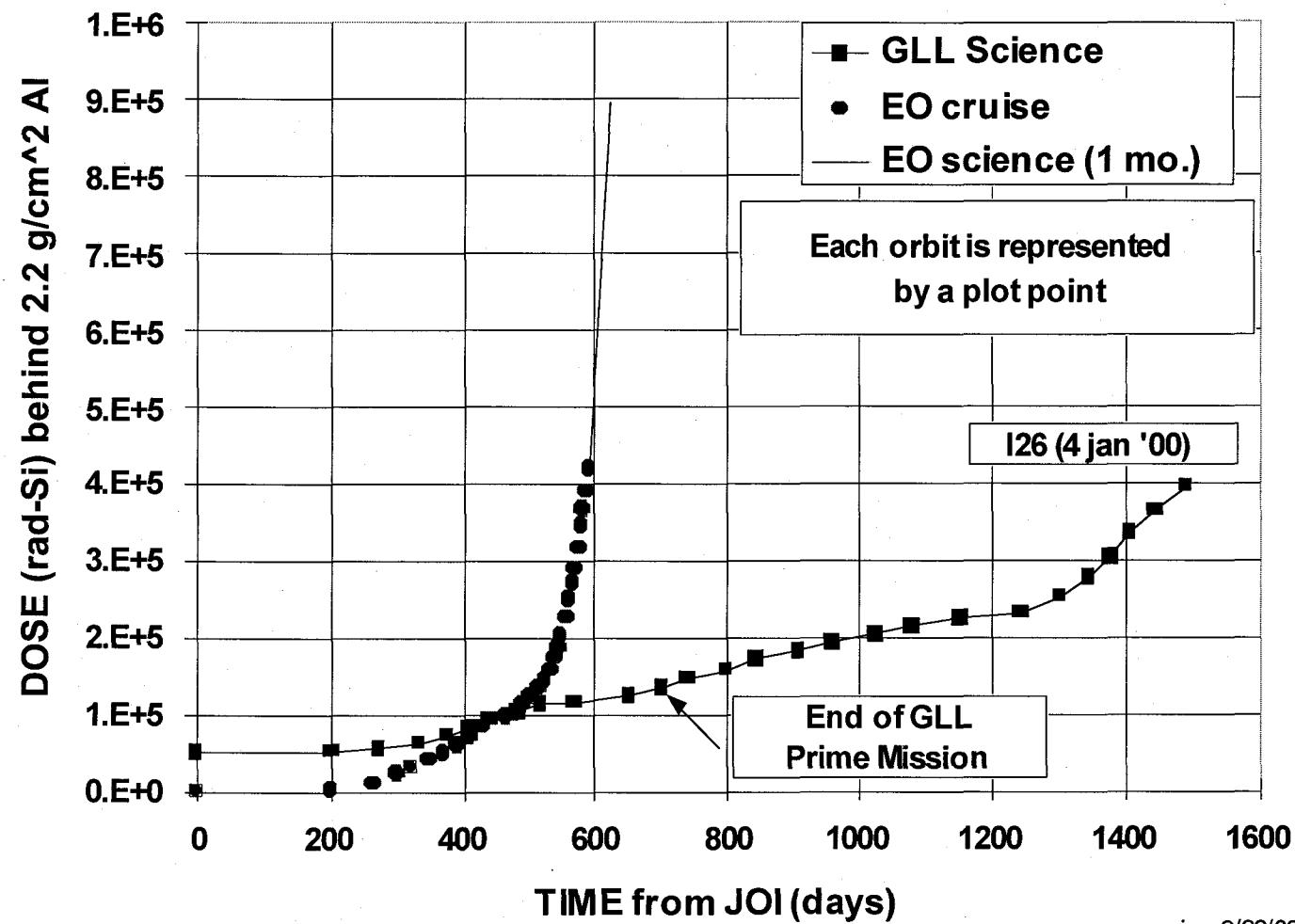
Divine-Garrett Model

# Average EPD High Energy Electron Flux per Orbit



Henry Garrett

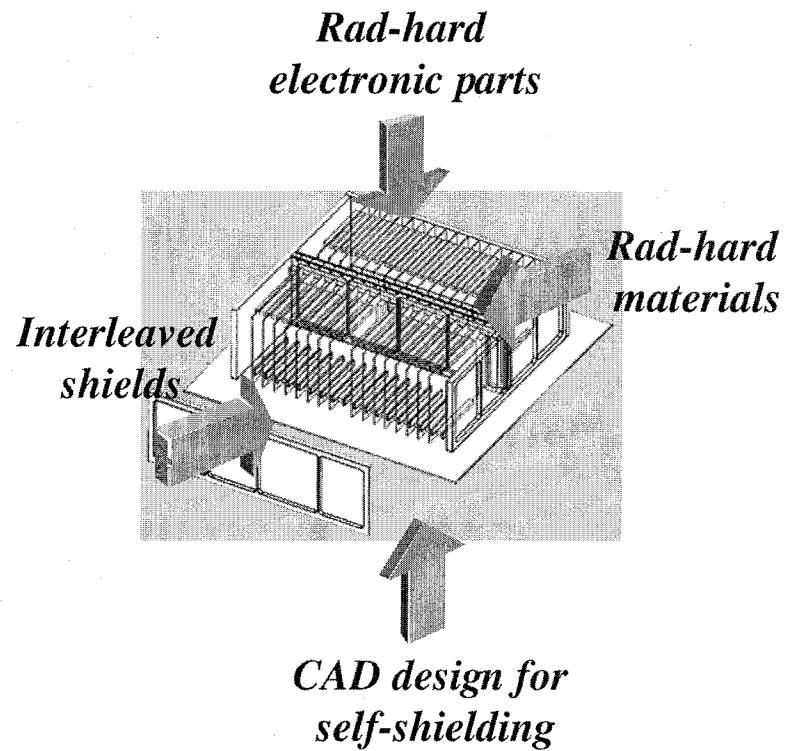
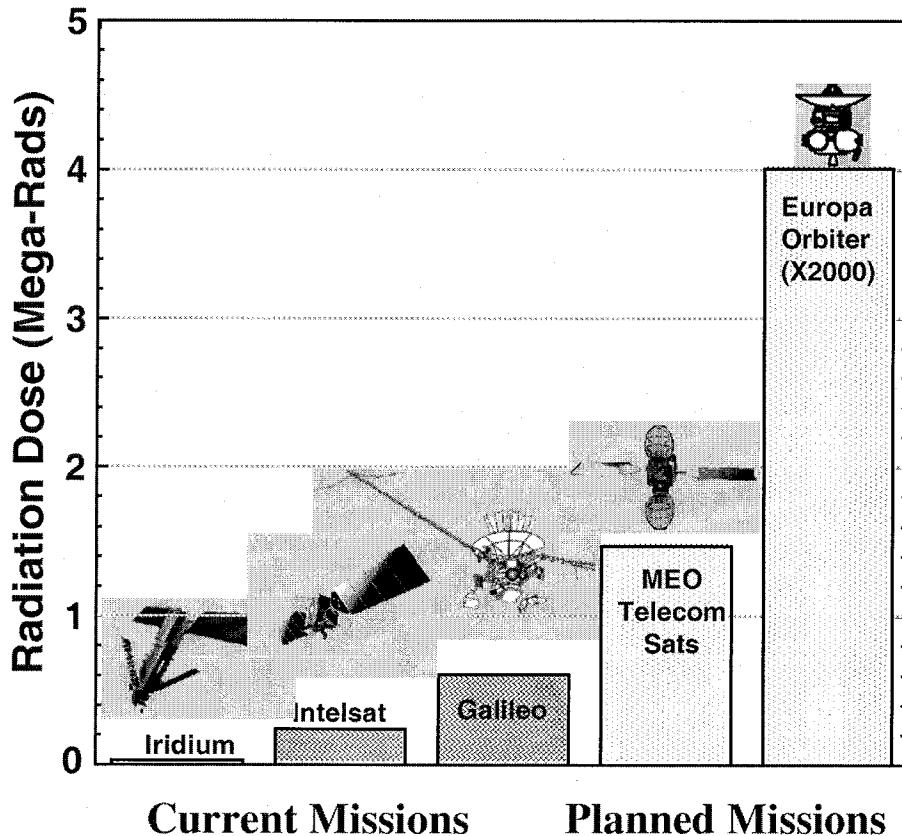
## Galileo and Europa Orbiter Missions: Radiation Profile.



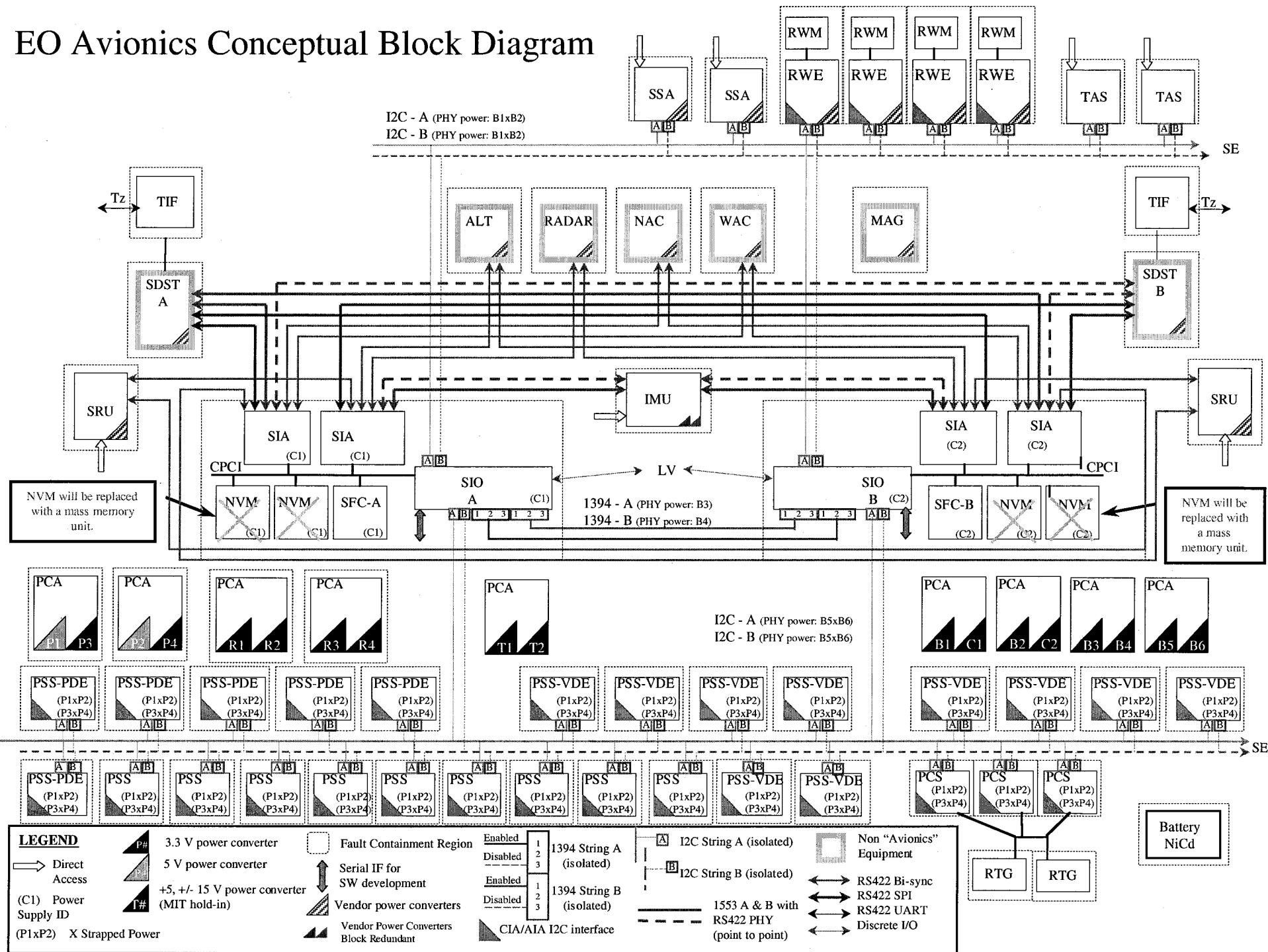
jmr 2/29/00



## *Reliability in Harsh Environments*



# EO Avionics Conceptual Block Diagram



# **Memory System for Europa Orbiter**

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## **History / the Need**

- X2000-developed NVM based on commercial Flash devices**
- Analysis and study show this solution is not workable for EO**

**The memory is too soft**

**Even massive shielding – can't show that there is a solution**

## **Status**

- EO de-scoped the X2000 NVM**
  - Initiated a study to identify an appropriate Memory System for EO**
- Final recommendations are due Mid Jan. 01**

## **Memory System for Europa Orbiter Top level Rqmts.**

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- **4.3 Gigabits OF ACTIVE DATA STORAGE CAPACITY (NOT INCLUDING EDAC)**
- **CONTINUOUS READ/WRITE DATA RATES UP TO 20 Mbps INCLUSIVE**
- **FUNCTIONAL NONVOLATILITY FOR AT LEAST 0.9 Gigabit OF STORAGE**
- **NO LOSS IN PERFORMANCE FROM A TID OF 1 Mrad (500 Krad(Si) ENVIRONMENT, RDF = 2) WHEN ENCLOSED IN THE EQUIVALENT OF AN X2000 INTEGRATED FIRST DELIVERY PROJECT (IFDP) ELECTRONICS CHASSIS IF NO ADDITIONAL SHIELDING IS PROVIDED**
- **UNCORRECTABLE DATA ERROR RATE LESS THAN  $10^{-10}$  BIT ERRORS PER DAY**
- **NO LOSS IN PERFORMANCE DUE TO A SINGLE FAILURE IN THE MEMORY SYSTEM, A PROCESSOR NODE, OR THE DATA BUS**
- **TOTAL MEMORY SYSTEM MASS LESS THAN 20 kg**
- **TOTAL MEMORY SYSTEM POWER LESS THAN 15 watts**

## CURRENTLY AVAILABLE CANDIDATE TECHNOLOGIES

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- FLASH EEPROM
- SYNCHRONOUS DYNAMIC RAM  
(DRAM)
- STATIC RAM (SRAM)
- DISK HARD DRIVES

# CANDIDATE TECHNOLOGIES REQUIRING HIGH RISK DEVELOPMENT

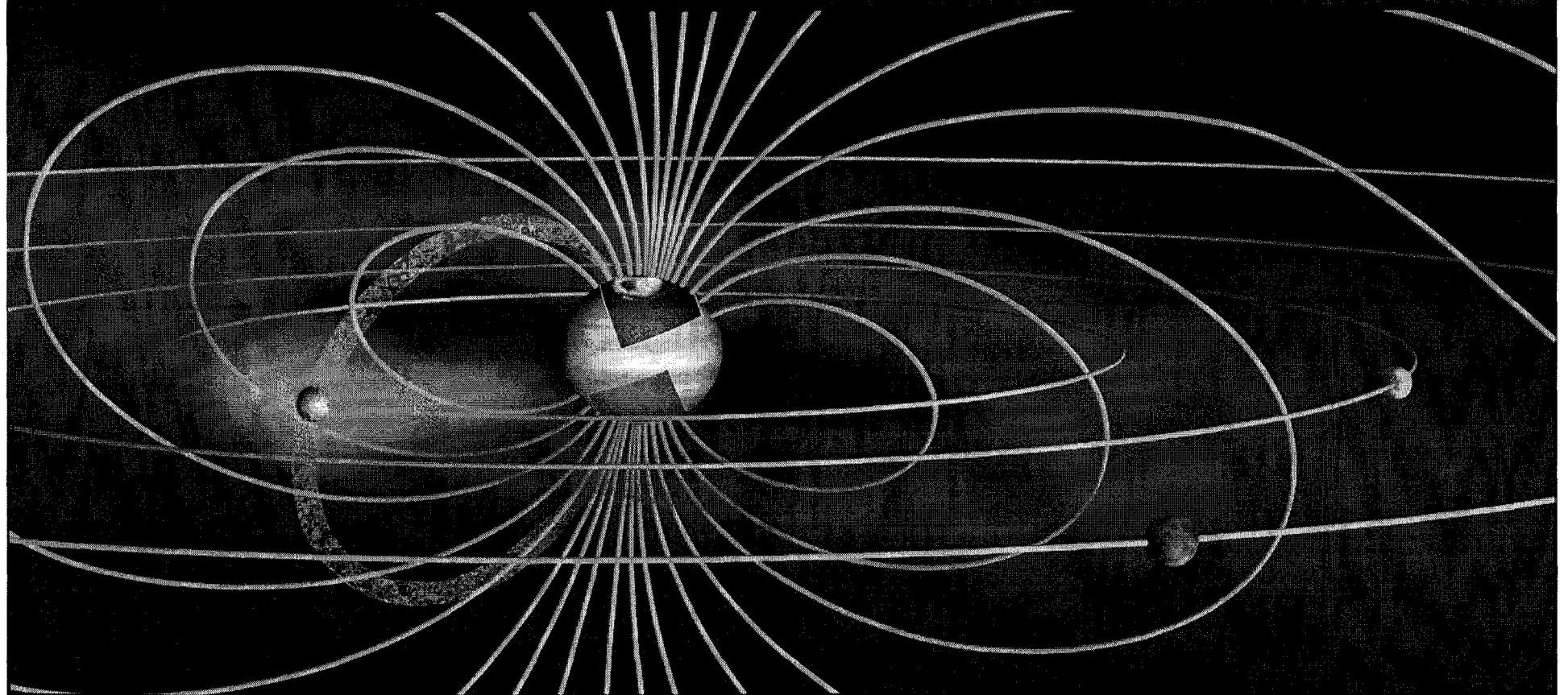
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- GIANT MAGNETORESISTIVE RAM (GMR RAM)
- FERROELECTRIC RAM (FeRAM)
- CHALCOGENIDE (CRAM)



# Satellite Magnetosphere Interactions



Courtesy of John Spencer, Lowell Observatory

## Backup Charts

## GLL/EO Radiation Design Comparison

Implementation	GLL	EO
Part Radiation Capability	Generally 150 krad, many >200 krads. No identified catastrophic failure	At least 100 Krads, most 1 Meg, some soft components that may catastrophically fail
WCA	EVA	EVA
RDM Verification	RCP	RCP
RDM	1.0 (Instruments) 2.0 (Engineering/SSI) 3.0 (Spot Shielded Parts)	2.0 (All)
Transport Analysis	NOVICE 3D Analysis SIGMA Ray Trace	NOVICE 3D Analysis
Environment Knowledge	+/- factor of two long term; unknown monthly variation	Good estimate of long term average; +/- factor of 3 monthly variation
S/C Design	Engineering bay provided shielding to meet RDM	Shielding provided at chassis/assembly level.
Mission Design	Science starts at JOI. Elliptical orbit allows part annealing	Science starts at EOI (60% of dose accumulated). Circular orbit at Europa does not allow for part annealing
Operations	Time for ground intervention with acceptable loss of science data	Little time for intervention between endgame and end of mission